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SHORT COMMUNICATION

IDENTIFYING HIGH-PERFORMING SEEDLING TEAS IN PASSARA, SRI LANKA

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Abstract

Tea is a shade-loving plant and is propagated either by seeds or cuttings. The seedling teas exhibit the ability to endure prolonged droughts while still achieving vigorous shoot growth. This study aimed to identify high-performing seedling teas in Passara where drought is a key determinant of tea yield. Twenty-one high-performing seedlings and six extensively-used vegetatively propagated tea cultivars from three randomly selected tea estates in Passara were compared morphologically based on shoot density, banji shoots, shoot weight, internodal length, length, and width of the mature leaf. Data were analyzed by analysis of variance (ANOVA) using Minitab (version 17) software. The findings demonstrated a significant difference among tea bushes considering selected morphological traits at a 5% significance level. Clustering analysis of Gonakele estate grouped GS4 with TRI 2025, GS2, and GS3 with TRI 2043. VS1 and VS3 seedlings from Varellapathna estate were clustered with TRI 2023 and CY9, respectively. Hopton estate seedlings did not cluster with vegetatively propagated cultivars. Therefore, GS2, GS3, GS4 from Gonakale, and VS1, and VS3 from Varellapathna were selected as mother bushes. Thus, the findings unveil distinct clusters of high-performing seedling teas from various estates, providing insights into potential candidates for maintaining genetic diversity in tea plantations.

Keywords: Seedling Teas, Drought, Morphological Comparison, Vegetatively Propagated Cultivars, Genetic Diversity

INTRODUCTION

Sri Lanka, formerly known as Ceylon, holds a rich heritage in tea production since the 19th century. Ceylon black tea is world-renowned for its unique aroma and flavor characteristics (Gunasekara 2012). The country's unique combinations of high altitude, cool climate, and fertile soil are ideal for the tea industry to serve as one of the main contributors to its economy (Wijeratne and Lanka 2018).

The quality of black tea is affected by various factors including tea cultivar, climatic conditions, topography, elevation, cultivation practices, processing technology, and storage conditions (Xu *et al*. 2018: Zhao *et al*. 2018). Based on elevation, Ceylon tea cultivation extends in three major areas: high grown ranging from 1200 m upwards, medium grown covering between 600 m to 1200 m and low grown from sea level up to 600 m (Jayasinghe *et al*. 2020). The central highlands and southern inland areas of the country are mainly devoted to tea cultivation. Nuwara Eliya, Dimbula, Uva, Uda Pussellawa, Kandy, Ruhuna, and Sabaragamuwa are recognized as the primary tea-growing regions that produce black teas with a diverse array of flavor profiles (Gunasekara 2012).

Tea may be propagated either by seeds or by cuttings. Tea cultivars are developed by the vegetative propagation from a single bush, raised from seed (Anandappa 1986). In large-

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scale multiplication, raising tea cultivars in land becomes an easy and efficient method. However, the cultivation of tea as a monocrop with cuttings reduces variability thus narrowing the genetic diversity (Raina *et al.* 2012: Xia *et al*. 2020). Further, the young clonal teas show extensive causalities during their first and second year after planting due to the exposure to harsh growing conditions including severe droughts or damages caused by pests and disease (Tea Research Institute 2011).

On the other hand, seedling teas are genetically diversified individuals that are adapted to grow in different environmental conditions (Nair 2021). Therefore, all the bushes in a seedling tea field may not be susceptible to severe growth conditions such as drought, pests diseases, *etc.* However, compared to seedling teas, the yield per hectare of vegetatively propagated (VP) cultivars is relatively high, allowing it to be extensively used in the tea estates.

Drought is a severe ecological concern that affects the production and productivity of cultivated crops, including tea (Nuskiya *et al*. 2021). The perennial nature of tea leaves it susceptible to the impacts of severe droughts. Because tea lands are rarely provided with an artificial irrigation system. Passara is located in the Uva region where tea liquors possess a special, unmistakable character and exotically aromatic flavor, one that is highly prized by trade and connoisseurs. This area is prone to experiencing prolonged drought conditions, which can have a detrimental effect on the growth and yield of tea plants.

The Tea Research Institute of Sri Lanka (TRISL) has introduced a series of tea cultivars including TRI 2000, 3000, 4000, and 5000 to counteract the effects of some factors that suppress the growth of tea including drought to ensure continued tea production. For instance, TRI 2025, and 2027 from TRI 2000 series, TRI 3013, 3019, and 3022 from TRI 3000 series, and TRI 4053 and 4061 from TRI 4000 series are recommended for cultivation in the Uva region due to the resistance to drought (Tea Research Institute 2002).

Excessive replanting programs are being conducted in Passara to replace old-seedling tea fields with VP cultivars for yield enhancement. This reduces genetic diversity, resulting in limited potential for future breeding. On the other hand, the number of superior cultivars available with drought tolerance and high-yielding characteristics is limited for the Uva region. Nevertheless, there is a potential to develop estate selections after conducting a careful investigation to identify the high-performing seedling teas in a particular region (Kottawa-Arachchi *et al*. 2016).

In tea estates, there are adeptly acclimated seedling teas that yield comparably to TRI-recommended cultivars. In 2017, Bandara has discovered that the high-performing seedlings in the Badulla can be recommended for serving as mother bushes and providing cuttings for nurseries. This conclusion was drawn based on a morphological comparison with extensively used VP cultivars in the same area.

Morphological characterization involves the examination of both qualitative and quantitative characteristics and is a critical aspect of plant phenotyping (Rahaman *et al*. 2015). It provides essential insights into genetic diversity, adaptations, and developmental patterns of organisms through the study of physical traits. Thereby, the researchers are able to infer genetic diversity while selecting superior individuals for breeding programs (Chaturvedi *et al*. 2022). Hence, morphological characterization is a tool for taxonomy, conservation, and breeding. The International Plant Genetic Resource Institute (IPGRI) and the International Union for the Protection of New Varieties of Plants (UPOV) have developed descriptor lists that guide the plant characterization process.

This study was conducted to perform a morphological comparison to identify high-performing old seedling tea bushes across three randomly selected estates in Passara. This comparison involved contrasting the seedlings with extensively used vegetatively propagated tea cultivars. Thus, the selected seedling tea bushes from different estates are recommended to be maintained as mother bushes to obtain cuttings for nurseries.

MATERIALS AND METHODS

Sample Collection

Fresh tea shoots were harvested on regular plucking rounds from the selected tea estates in the Passara area based on the agroecological region and production. Gonakale estate belongs to Namunukula Plantations Limited (IM2), Hopton estate of Hapugastanne Plantations Limited (IU2), and Verellapathna estate of Madulsima Plantations Limited (IU2) were the selected three (03) plantations. Five high-performing seedling tea bushes and three extensively used VP cultivars were randomly selected from each estate under the guidance of estate managers, and field officers of the estates and based on previous yield data. DN, CY9, TRI 2023, TRI 2025, TRI 2027, and TRI 2043 were the extensively used VP cultivars in the selected estates. These cultivars are recommended by TRISL, particularly for the Uva region as the drought-tolerant varieties.

Morphological Characterization

Tea yield is determined by the healthy and vigorous growth of young tea shoots. A bud with one leaf, two leaves, and/ or three leaves and immature banji shoots are plucked for black tea manufacture (Kumar *et al*. 2012: Ponmuruga *et al*. 2019). Therefore, the morphological characters associated with shoot growth were considered during this study. In morphological characterization, the plant descriptors provided by the International Plant Genetic Resource Institute (IPGRI) and the International Union for the Protection of New Varieties of Plants (UPOV) were considered. The collected data on selected morphological traits were scored based on the descriptions provided by the descriptors. The third leaf from the top of the flush shoots was selected for characterization because it serves as the mother leaf for the next shoot generation. Further, the shoots with a bud and two leaves were plucked from the bushes for evaluation.

Six quantitative morphological characteristics (number of pluckable shoots per bush, the number of banji shoots per bush, the weight of pluckable shoots, the length of the mature leaf, the width of the mature leaf, internodal length) were used to obtain the data on each tea bush (Table 1: Descriptors selected for the study).

Data Analysis

Analysis of variance (ANOVA) and mean comparison were conducted using Minitab 17 software. Cluster analysis was conducted for all considered characteristics to cluster them in facilitating the identification of their genetic relatedness which helps to exploit the phenotypic variations at their genotypic level.

RESULTS AND DISCUSSION

The previous yield reports and the advice from assistant superintendents and field officers of each estate were taken into account in the selection of tea bushes for the study. In line with this, seedling tea bushes were carefully selected from the Gonakale tea estate, and subsequently labeled as GS1, GS2, GS3, GS4, and GS5. The identified tea bushes were then compared against TRI 2025, DN, and TRI 2043, which were recognized for their high-yield potential within the estate.

The seedling and VP tea bushes selected from the Gonakale tea estate were examined for the above-mentioned plant descriptors (Table 2). Statistical analyses revealed that the p-values for each of these characteristics were below 0.05, indicating significant differences between the selected tea plants. Notably, the GS1 seedling exhibited the highest mean number of pluckable shoots (24.66), while the GS5 seedling displayed the highest mean values for both banji shoot count (6.67) and weight of pluckable shoots (17.110 g). The highest mean values for mature leaf width (4.12 cm) and length (8.46 cm), on the other hand, were observed in a VP cultivar (TRI 2025). Finally, TRI 2043 had the highest mean value for the internodal length (5.64 cm).

As well, seedlings selected from the Hopton tea estate, namely HS1, HS2, HS3, HS4, and HS5, were compared with extensively used VP cultivars of the estate (CY9, TRI 2043, and TRI 2023). The scored data of all the se-

Table 1: Descriptors selected for the study

Descriptor	Description	Reason for selection
Shoot density	Number of pluckable shoots in the plucking table of the bush	An indication of the increased tea yield One of the yield components of a tea bush
Shoot weight	Weight of pluckable shoots in the plucking table of the bush	An indicator of the amount of photosynthesizing mesophyll tissue in a leaf One of the yield components of a tea bush
Banji shoots	Number of banji shoots in the plucking table of the bush	An indication of the shoot dormancy and yield reduction
Internodal length (cm)	Distance between the 3rd and 4th leaves from the top of a flush shoot. An average of 10 shoots exposed to full sunlight from each bush	An indication of the decrease of leaf density in a bush that reduces tea yield
Length of the mature leaf (cm)	Recorded on the 3rd leaf below the apical bud. An average of five leaves from a bush was used to take measurements from each bush	An indication of healthy vigorous growth and high yield of a tea bush
Width of the mature leaf (cm)	The width of the mature leaf was recorded on the 3rd leaf below the apical bud. An average of five leaves from a bush was used to take measurements from each bush	An indication of healthy vigorous growth and high yield of a tea bush

lected quantitative traits showed p-values below 0.05 which indicates the significant difference between the selected tea bushes in consideration of the selected traits. Interestingly, the highest mean values for the number of pluckable shoots (23.00), weight of pluckable shoots (16.01), length of mature leaf (9.44 cm), and width of the mature leaf (3.940 cm) were observed from TRI 2023. HS3 resulted in the highest mean value for the banji shoots (10.667) which is an indicator of the poor growth of the bush. And, TRI 2043 showed the highest mean value for internodal length, 4.300 cm.

The findings indicate that the selected seedling teas in Hopton tea estates exhibit suboptimal growth and development compared to the VP cultivars under consideration. It could be attributed to inadequate field management practices in the seedling field. Further, during the study period, the estate's priority was to replace the seedling tea fields with the VP cultivars, which were known to yield the highest output, in a bid to maintain economic stability. However, the selection of tea cultivars suitable for the region is a crucial factor. VP tea clones are more vulnerable to droughts, pests, and disease problems due to the uniformity (Wijeratne 2018).

The selected seedlings from the Varellapathna estate were labeled as VS1, VS2, VS3, VS4, and VS5. TRI 2023, CY9, and TRI 2027 were the prominent VP tea cultivars in the estate that were selected to compare with the selected seedling teas. Similar to the other two estates, the selected tea bushes showed a significant difference from each other in consideration of the given plant descriptors due to a lower value than 0.05. Mean comparison analysis showed that the highest mean value for the number of pluckable shoots (34.00) was recorded by VS5 seedling. TRI 2027 showed

Table 2: Mean values, categories, and p-values obtained for quantitative traits of the selected tea cultivars and seedlings

Tea Estate	Tea cultivar or seedling	Shoot Density	Banji shoots	Shoot Weight (g)	Length of the mature leaf (cm)	Width of the mature leaf (cm)	Internodal length (cm)
Gonakale estate	GS1	24.66 ± 0.01^{a}	3.33 ± 0.56^{a}	11.25 ± 0.20^{ab}	5.5 ± 0.20^{b}	2.44 ± 0.33^{d}	3.38 ± 0.08^{bc}
	GS2	12.33 ± 0.21^{de}	5.00 ± 0.00^{a}	12.57 ± 0.88^{ab}	7.66 ±0.73^{ab}	3.64 ± 0.32^{ab}	3.84 ± 0.88^{bc}
	GS3	16.33 ± 0.06^{bcde}	6.33 ± 0.01^{a}	16.66 ± 0.96^{a}	7.28 ± 0.28^{ab}	3.40 ± 0.29^{abc}	3.45 ± 0.40^{bc}
	GS4	20.33± 0.48^{abc}	4.33 ± 0.79^{a}	13.82 ± 0.71^{a}	7.32 ± 0.29^{ab}	3.62 ± 0.80^{ab}	3.30 ± 0.29^{bc}
	GS5	24.00 ± 0.10^{ab}	6.66 ± 0.93^{a}	17.11 ± 0.22^{a}	7.56 ± 0.84^{ab}	2.64 ± 0.40^{cd}	2.70 ± 0.68^{c}
	DN	11.33 ± 0.15^{e}	3.33 ± 0.03^{a}	7.02 ± 0.27^{b}	7.64 ± 0.35^{ab}	3.22 ± 0.38^{abcd}	3.13 ± 0.78^{c}
	TRI 2025	19.67 ± 0.98^{abcd}	2.00 ± 0.00^{a}	13.79 ± 0.05^{a}	8.46 ± 0.79^{a}	4.12 ± 0.46^{a}	4.72 ± 0.28^{ab}
	TRI 2043	16.00 ± 1.00^{cde}	2.33 ± 0.04^{a}	11.42 ± 0.01^{ab}	8.08 ± 0.96^{a}	3.16 ± 0.36^{bcd}	5.64 ± 0.46^{a}
	P- values	*0.000*	*0.037*	*0.001*	*0.034*	*0.000*	*0.000*
Hopton tea estate	HS1	8.66 ± 0.00^{c}	9.33 ± 0.81^{a}	10.65 ± 0.09^{bcd}	7.86 ± 0.12^{ab}	3.16 ± 0.45^{ab}	1.96 ± 0.51^{c}
	HS2	6.67 ± 0.01 ^{c}	8.33 ± 0.01^{a}	7.69 ±0.37^{d}	7.52 ± 0.53^{ab}	3.10 ±0.37^{ab}	1.92 ±0.63^{c}
	HS3	7.00 ± 0.00^{c}	10.66 ±0.15^{a}	12.22 ± 0.82^{abc}	7.44 0.30^{ab}	3.30 ± 0.66^{ab}	1.81 ±0.63^{c}
	HS4	9.00 ± 0.00^{c}	1.33 ± 0.16^{a}	13.38 ± 0.43^{abc}	7.60 ± 0.89^{ab}	2.90 ± 0.21^{b}	1.82 ± 0.91^{c}
	HS5	10.00 ±0.00^{bc}	5.00 ± 0.00^{ab}	9.75 ± 0.82^{bcd}	6.94 ± 0.09^{b}	2.78 ± 0.47^{b}	3.49 ± 0.23^{ab}
	CY9	17.00 ± 0.00^{ab}	1.33 ± 0.30^{b}	9.66 ± 0.81^{cd}	8.36 ± 0.58^{ab}	3.50 ± 0.08^{ab}	3.43 ± 0.19^{ab}
	TRI 2043	19.33 ± 0.11^{a}	1.33 ± 0.15^{b}	13.54 ± 0.25^{ab}	7.12 ± 0.76^{b}	3.16 ± 0.38^{ab}	4.30 ± 0.25^{a}
	TRI 2023	23.00 ± 0.00^{a}	0.00^{b}	16.01 ± 0.41^{a}	9.44 ± 0.99^{a}	3.94 ± 0.41^{a}	2.82 ±0.09^{bc}
	P- values	0.000	0.000	0.000	0.014	0.015	0.000

Table 2: Contd….

Varellap athna estate	VS1	25.00 ± 0.00^{abc}	5.33 ± 0.13^{ab}	15.14 ± 0.13^{ab}	6.46 ± 0.76^{bc}	2.74 ± 0.22^{cd}	2.29 ± 0.56^{c}
	VS2	33.00 ± 0.00^{ab}	4.33 ± 0.21^{ab}	18.80 ± 1.23^{ab}	6.08 ± 0.21^{bc}	2.52 ± 0.16^{cd}	2.41 ± 0.21^{c}
	VS3	19.00 ± 0.00^{c}	5.00 ± 0.99^{ab}	9.96 ± 0.51^{b}	7.18 ± 0.85^{bc}	3.20 ± 0.20^{abc}	2.49 ± 0.84^{c}
	VS4	28.00 ± 0.00^{abc}	2.00 ± 0.01^{b}	21.72 ± 1.12^{a}	7.94 ± 1.06^{ab}	2.98 ± 0.39^{bcd}	4.43 ± 0.05^{a}
	VS5	34.00 ± 0.00^{a}	5.67 ± 0.56^{ab}	19.11 ± 0.88^{ab}	5.64 ± 0.63^{c}	2.3 ± 0.20^{d}	3.04 ± 0.90^{bc}
	TRI 2023	20.67 ± 0.02^{bc}	7.67 ± 0.47^{ab}	15.00 ± 1.09^{ab}	7.58 ± 0.50^{bc}	3.68 ± 0.53^{ab}	3.34 ± 0.72^{abc}
	CY9	18.00± 0.00c	10.00 ± 1.41^{a}	10.18 ± 1.12^{b}	7.86 ± 1.46^{ab}	2.86 ± 0.54^{bcd}	$3.670\ 0.54^{ab}$
	TRI 2027	25.00 ± 0.00^{abc}	1.00 ± 0.80^{b}	10.09 ± 1.78^{b}	9.86 ± 1.01^{a}	3.84 ± 0.37^{a}	2.760 ± 0.56^{bc}
	P- values	*0.004*	*0.023*	*0.002*	*0.000*	*0.000*	*0.000*

The different superscript letters indicate a statistical significance ($p \leq 0.05$). Data are expressed as mean ± standard deviation (n=3).

the lowest value for the number of banji shoots (1.00) as well as the highest mean values for both length (9.869 cm) and width of the mature leaf (3.84 cm). Meanwhile, VS4 and VS5 seedlings recorded the highest mean value for the internodal length (4.43 cm) and the weight of pluckable shoots (21.72 g), respectively. Dendrograms were constructed separately for each estate for all the morphological traits considered to select the best seedlings.

The dendrogram of the Gonakale estate (Figure 1) shows the main two clusters at a similarity level of approximately 50. The GS4 seedling and TRI 2025 grouped for all the quantitative traits according to the mean comparison. Further, both GS2 and GS3 seedlings formed a cluster with TRI 2043.

However, the clustering pattern of the Hopton estate (Figure 2) illustrated two main clusters which include chosen seedlings and VP cultivars separately.

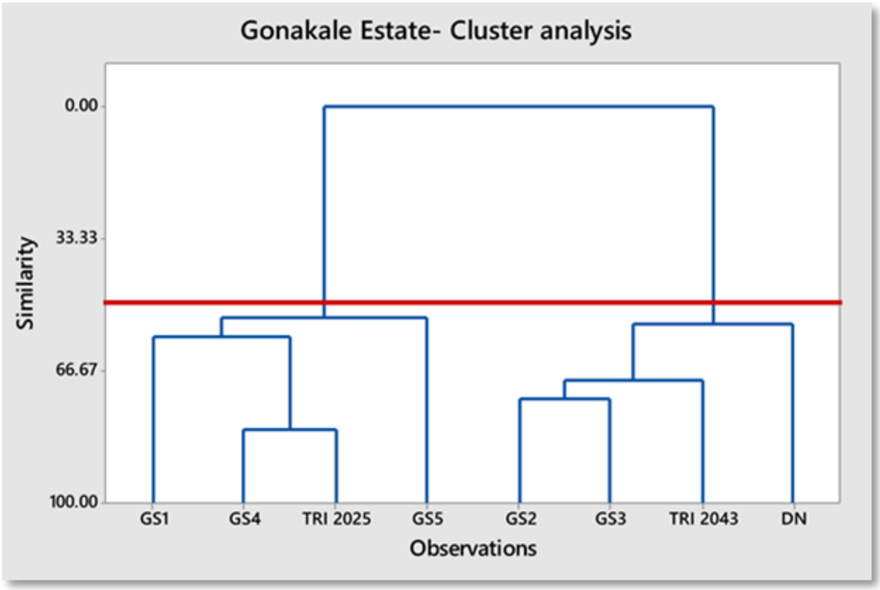

Figure 1: Clustering pattern of morphological traits for Gonakale Estate

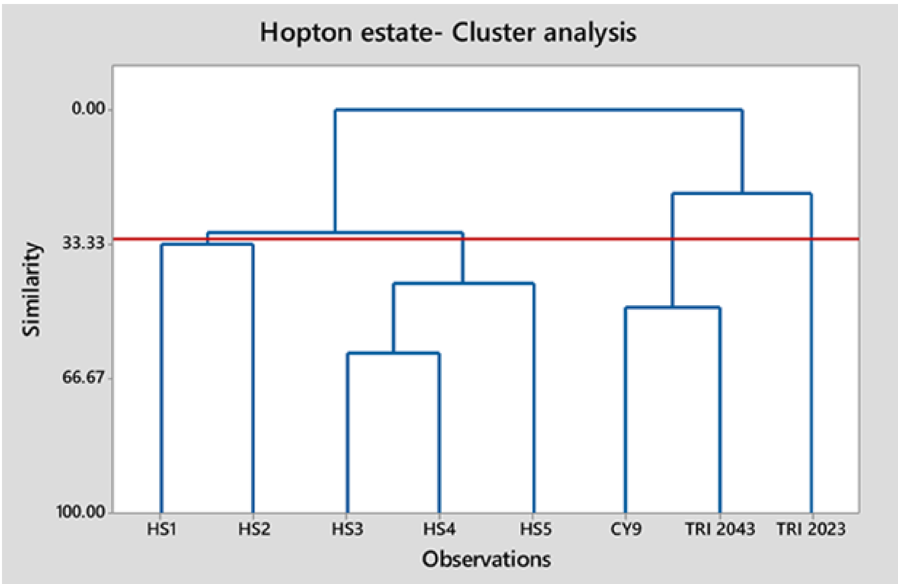

Figure 2: Clustering pattern of morphological traits for Hopton estate

In the given clustering pattern of Figure 3 for the Varellapathna estate, three different clusters can be identified at a similarity level of approximately 50. In cluster 1, the VS1 seedling and TRI 2023 tea cultivar have been clustered together for all the quantitative characters considered except for the width of the mature leaf. TRI 2027 was also clustered together with VS1 and TRI 2023 sub-cluster. VS3 seedlings and CY9 tea cultivars (cluster 2) were grouped for the number of pluckable shoots (Shoot density), the number of banji shoots, the weight of pluckable shoots, and the width and length of a mature leaf. Both TRI 2023 and TRI 2027 have been highly recommended as cultivars that yield abundantly in the Uva region. Additionally, CY9 and TRI 2027 have been identified as varieties with excellent drought tolerance (Tea Research Institute 2002).

According to the results obtained from the study, some of the selected tea bushes can be recommended to take cuttings for nurseries and maintained as mother bushes. For the Gonakale tea estate, GS2, GS3 and GS4 seedlings are recommended because they show similarities to TRI 2025 and TRI 2043. According to Damayanthi *et al*. (2010), TRI 2025 is a drought-tolerant cultivar with the lowest drought susceptibility index (0.81) that is also recognized as a high-yielding cultivar (Tea Research Institute of Sri Lanka 2002). Also, the VS3 seedling from the Varellapathna estate is most similar to CY9 which is known to be a drought-tolerant estate clone (Damayanthi *et al*. 2010). VS1 seedling from Varellapathna tea estate is clustered together with TRI 2023 and TRI 2027 cultivars, hence, can be maintained to obtain planting materials. The selected seedling teas from Gonakale and Varellapathna tea estates are shown in Figure 4.

The extensive replanting programs of Hopton estate that replace old seedling teas with VP tea cultivars may have a significant influence on the failure of the management of good agricultural practices in the existing seedling tea fields. Therefore, it is difficult to select seedlings from the Hopton estate because the similarities were unrecognizable between seedlings and VP cultivars as they have been clustered separately.

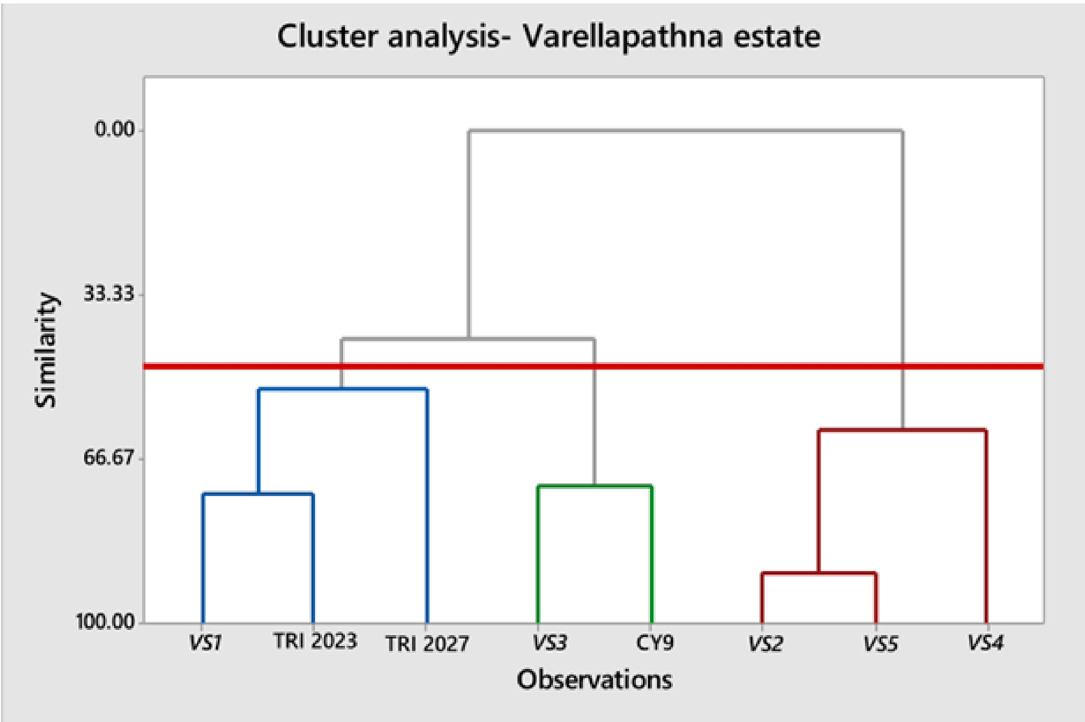

Figure 3: Clustering pattern of morphological traits for Varellapathna estate

Figure 4: Selected seedlings from Gonakale and Varellapathna Estates to maintain as mother bushes (a) GS2 (b) GS3 (c) GS4 (4) VS1 (5) VS3

CONCLUSION

The results revealed that the selected tea bushes were significantly different from each other in consideration of the morphological traits (number of pluckable shoots per bush, the number of banji shoots per bush, the weight of pluckable shoots, the length of the mature leaf, the width of the mature leaf, internodal length) at 0.05 level of significance.

According to the cluster analysis, VS1 and VS3 seedlings from the Varellapathna estate were clustered with TRI 2023 and CY9, respectively. Clustering analysis of Gonakele estate grouped GS4 with TRI 2025, GS2, and GS3 with TRI 2043 for all the quantitative traits considered. Hopton estate seedlings did not cluster with vegetatively propagated cultivars. Further, VS3 and GS4 seedlings scored for the selected morphological traits similar to CY9 and TRI 2025, the drought-tolerant cultivars recommended by TRISL, especially for the Uva region. Therefore, GS2, GS3, GS4 from Gonakale, and VS1, and VS3 from

Varellapathna were selected as mother bushes to take cuttings for nurseries under a proper breeding program.

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AUTHOR CONTRIBUTION

Alwis designed the study. Hettiarachchi collected data and analyzed it under the supervision of Alwis and Dharmarathna and wrote the article under the supervision of Dharmarathna.

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